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Comparison of Methods
of Sewage Purification

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COMPARISON OF METHODS
OF
SEWAGE PURIFICATION

BY

THEODORE CLIFFORD PHILLIPS
AND
EDWARD JOHN SCHNEIDER

THESIS

FOR DEGREE OF BACHELOR OF SCIENCE
IN MUNICIPAL AND SANITARY ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE 1900

1900
P54

54

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May 31, 1900. 190

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Theodore Clifford Phillips and Edward John Schneider

ENTITLED Comparison of Methods of Sewage Purification

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Municipal and Sanitary Engineering.

Arthur N. Talbot

HEAD OF DEPARTMENT OF Municipal and Sanitary Engineering.

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Comparison of Methods of Sewage Purification.

The disposal of sewage is one of the most important problems that confront the municiple and sanitary engineer to-day.

The study of this subject dates back to 1844 when the Healths of Towns Commission of London made the report which first showed the real course of the rapid increase in the death rate of the larger cities. In this country practically nothing was done until 1872 when the Massachusetts Legislature instruct the State Board of Health to investigate and report on the subjects of sewerage, sewage disposal, and the pollution of streams, and to-day Massachusetts

leads in the investigation of the best methods of sewage disposal.

Six different methods for the treatment of sewage are now in use. These methods are used separately or in combination, the choice depending upon local conditions and the amount of purification required:-

These methods are:

1- Dilution.

2- Irrigation.

3- Intermittent Downward Filtration.

4- Chemical Precipitation.

5- Septic Tank.

6- Contact Bed.

The purpose of this thesis is to investigate each method and make a comparison along the following lines:

1- Purification.

2- Capacity.

3- Applicability.

4- Cost.

Dilution

Disposal of sewage by dilution is the most common method at the present time, and no doubt will continue to be for some time to come where the stream or body of water is not used for domestic purposes. Under certain conditions this affords a satisfactory solution of the problem. However, if the water into which the sewage is discharged is a source of water supply, two very important questions arise. They are: 1- How large must the dilution be? 2- How far must the polluted stream flow before the water may be used with safety to public health?

In 1867 Dr. Letheby and others in England made the statement that if sewage is diluted at least twenty times its volume, it will not only be made inoffensive but be thoroughly destroyed after flowing a dozen miles or more.

The Rivers Pollution Commission of Great Britain in 1878 maintained that no river in England was long enough to allow of a complete disappearance of sewage matter discharged into it.

Mr F. P. Stearns in an article on The Pollution and Self-Purification of Streams in the Massachusetts State Board of Health Report 1890 gives a table showing "The calculated composition of sewage for different degrees of dilution in a running stream". A comparison was made of the Blackstone and Merrimack rivers, and extended over three years. It was from this investigation that the Commission of the City of Chicago reported that the flow of the Chicago Drainage Canal should be four cubic feet per second per 1000 inhabitants.

The purification by dilution may be due to three things:

1 Oxidation of organic matter.

2 Subsidence.

3 Destruction of the organic matter by small animals and plants.

The oxidation is a very slow process and depends mainly upon bacterial life and conditions favorable to it. Subsidence depends upon the difference in the specific gravity of the suspended matter, and the clarification is increased as the velocity is diminished.

In regard to the destruction of the organic matter by small animals and plants Dr. Sardy says, (Journal Royal Microscopic Society, 1884 pp. 988.) "It appears to me that the removal of impurities from rivers is more of a biolytic than a chemical question, and it is most important to consider the action of minute animals and plants, which may be looked upon as being indirectly most powerful agents.

Irrigation

Although the method of broad irrigation has been carried on successfully in several of the largest cities of the old world it has not been used to any great extent in the United States, except at a few state institutions in the east, and in the arid districts of the west.

Several years ago this method of disposal was given much attention as it was thought the sewage fund would yield large profits, but more recent information shows conclusively that such is not the case.

Perhaps the most noticeable examples of this system that are now in operation in the United States are the plants at the State Hospital of the Insane, Worcester, Mass., at the Rhode Island State Institute, and at the Reformatory at Concord, Mass. In all cases the labor was done by the inmates so that it is not

possible to get a fair statement of the cost. General information regarding the use of sewage for irrigation in the west may be obtained from Baker and Rafters' "Sewage Disposal in the United States."

Undoubtedly the best example of sewage farming is at Berlin. The following summary is given by James H. Fuertes, M. Am. Soc. C. E., in No 2. Vol. 40 of the Engineering Record. The average quatity of sewage pumped to the farms and distributed amounts to from 6000000 to 7000000 gallons per acre per year, or in other words each acre serves for 750 people. The area farmed is divided into small beds about 150 by 200 feet separated from each other by slight embankments and ditches for distributing the sewage over the surface. The sewage is admitted into the carriers from the force mains through checking chambers made of woven willow and posts driven into the sand.

The farms are said to yield small

profits over the expenses of working them, consequently contribute scarcely anything toward the cost of pumping the sewage.

The great reason why this method of disposal has been possible and profitable in a degree at Berlin is that this large and beautiful city lies in the midst of an extensive sandy area, the greater part of which in the immediate neighborhood is quite sterile and therefore comporatively thinly-populated. Better conditions for such sewage farms could not exist.

Statistics compiled by Chas. S. Swan M. Am. Soc. C.E. in his paper Notes on European Practice in Sewage Disposal in Jour. Assn. of Eng. Soc. Vol. 7 No. 9. shows the volume of sewage per acre per day (yearly average) to vary from 2154 to 21450 gallons, and the average depth per annum varies from 2.4 to 32.8 feet.

The nineteenth annual report of

the Massachusetts State Board of Health 1888 states that on an ordinary farm in Massachusetts 2500-gallons per acre per day are as much as could be applied to any valuable grass crop. This would require such a large area for large cities that irrigation could not be depended upon for preventing the pollution of streams.

It is evident from the above report that the irrigation system can be used to advantage only where large tracts of low land can be obtained at a low cost, and where help and pleanty of cheap labor can be obtained.

Intermittent Downward Filtration

Filtration means the concentration of sewage on an area of especially chosen porous ground, or on an especially prepared bed as small as will absorb and purify it. The intermittency of application is a necessary requirment even in suitably constituted soils wherever complete success is aimed at. The reason for this is that free oxygen is indispensable to nitrification and the nitrifying organism.

This method has been in operation only during the last thirty years and the correct theory of its action has been found out within the last ten years

Dr Frankland in the first report of Rivers Pollution Commission of England shows that not only a chemical action but also a biolytic action takes place with the assistance of minerals and the oxygen of the air. This biolytic action is known

as nitrofaction, and consists in the oxidation of the nitrogen of ammonia and its ultimate conversion into nitric acid. This change takes place in two stages each characterized by a distinct organism. The office of one of these organisms is to convert ammonia into nitrite, while the other converts nitrite into nitrate

The bacteria are present or quickly develop in the sewage which may be considered a nutrient medium for them by reason of containing a large amount of their natural nitrogenous food.

These organisms according to Warington may be separated by successive cultivations in favorable media; from a potassium nitrate solution with no ammonia we may obtain nitric organism alone; from an ammonium carbonate solution we may obtain nitrous organism in a pure state

It is a noticeable fact that frost

checks nitrification, but several satisfactory methods have been used so that no serious objection can be raised to intermittent filtration on this ground.

"The purification of sewage by this method depends upon the oxygen and the time of action" (Hazen) To obtain the highest efficiency the sewage must be applied intermittently and there must be a large percentage of voids in the sand.

Experiments made on especially prepared beds at Lawrence Mass. show that by treating 85000 gallons per acre per day, 94 percent. of the organic matter and 98 percent of the bacteria are removed, and by treating 60000 gallons per acre per day 97 to 99 percent of the organic matter may be removed. The above data shows that 100,000 may be successfully treated with a five foot bed of sand.

The writers inspected the inter-

without downward filtration plant at Mendota Illinois and the following data were obtained. The city has a population of about 6000 with 8 miles of sewers and 210 house connections. The average daily flow is about 350000 gallons although during the rainy season there is a considerable amount of ground water present.

The disposal plant was constructed under the supervision of the Iowa Engineering Company of Clinton. Iowa, on a 15 acre tract of land, one and a half miles south of the city. Although original plans called for 18 beds with five feet of gravel, only four beds each 275 feet by 75 feet were finished, and instead of 5 feet of gravel. only 24 inches was used. The plant was completed in July 1899 and was operated until December, when it was discontinued on account of cold weather, it not being considered necessary to operate it during the

winter. From December until April the sewage was discharged directly into a creek which runs along one side of the land.

The beds have no automatic device for distributing the sewage at definite intervals of time, but are connected with the main sewer by a number of gate valves which were regulated by the attendant. The sewage is distributed by means of a wooden sluice way which extended the entire length of the bed and has six inch openings on the side every 16 feet which gave a fairly even distribution.

Although no analysis of the sand and gravel was made, it was apparent that the uniformity coefficient was very large.

The material was shipped a distance of 90 miles and resembles ordinary ballast used for rail roads. The largest pieces were thrown along the sluice way to prevent excessive washing. The finest of the sand

was of a size which would be considered too fine for good mortar sand. No attempt was made to screen the material. The gravel would not be considered first class for filtering beds.

Samples of the sewage and effluent were taken at two different times. The first was between 9:00 and 10:30 A.M., April 20, 1900. Until the day before no sewage had been applied to the beds since last fall The second collection was made two weeks later, when samples of the sewage and effluent were collected at intervals of one hour during the day, and mixed into composite samples. The sewage was taken from a manhole just above the beds, and the effluent from the outlet of the underdrain about 900 feet below the beds

The analyses is given in Table I. and the results show that the beds are not working as efficiently as might be expected from a first class plant. This may be accounted for

from the fact that the filtration is too rapid and that the material which is less than two feet in depth is not suitable for such a purpose.

TABLE I.

Analyses of Sewage and of Effluent from Intermittent Downward Filtration Plant at Mendota. Ills.

Parts per 1,000,000

	April 20. 1900			May 4. 1900.		
	Sewage	Effluent	Efficiency	Sewage	Effluent	Efficiency
Oxygen consumed: Total	48.5	6.50	86%	27.7	12.0	55%
In suspension.	33.4			15.5	4.6	70%
In solution.	15.1			12.2	7.4	40%
Nitrogen as albuminoid ammonia						
Total	10.4	.32	97%	3.68	.768	79%
In suspension	9.28			2.816	.416	85%
In solution	1.12			.864	.352	59%
Total organic nitrogen	17.960	.920	95%	9.60	1.860	81%
In suspension	15.04			7.500	1.152	85%
In solution	2.92			2.100	.708	66%
Nitrogen as free ammonia	7.20	2.40	67%	3.84	1.28	67%
" as nitrites	.675	.375		000	000	
" as nitrates	4.00	18.00		.120	.120	
Chlorine as chlorides.	53.0	49.0		47.0	44.0	

Chemical Precipitation

When certain chemicals are added to sewage a precipitate is formed which under favorable conditions may carry down with it all the suspended matter as well as a portion of the dissolved organic matter. The addition of the chemicals together with the working of the various appliances for grinding and mixing the same, the decanting of the effluent, and the caring for the sludge all constitute what is known as the chemical treatment of sewage, the complete process being in reality partly chemical and partly mechanical.

The following matter concerning the theory of precipitation is taken from Baker and Rafter's Sewage Disposal.

The reagents chiefly used at the present time are lime, sulphate of alumina, and ferrous sulphate. In the case of lime there is a

combination of some of the lime and with free and partially combined carbon dioxide to form an insoluble carbonate of lime. There is probably a further combination of an additional part of the lime with a portion of the organic matter in solution. The insoluble substances so formed sink to the bottom, carrying with them the major portion of the suspended matter in the sewage in the form of sludge

Sulphate of alumina exercises a precipitating effect by a combination of the sulphuric acid with lime while alumina hydrate forms a flocculent precipitate which entangles and carries down the suspended organic matters

On November 11-1899 the writers visited the chemical precipitation plant at Madison Wisconsin and through the kindness of Mr. Mc Clellan Dodge, City Engineer, were shown the plant at that time in operation.

The sewage was screened as it

come from the city and emptied into a well. Here it was dosed with lime and then pumped to one of the four settling tanks. These are 15 feet deep and 12.5 feet in diameter. The sewage enters near the bottom of the tanks. The sludge settles to the bottom and the effluent rises to the top where it is carried away to three of the filter beds. These three beds are in continuous use. A fourth beds is out of use while it is washed and allowed to rest for one day.

The total area of the beds is 5550 square feet. The flow through the beds is about 8000000 gallons per acre per day.

The company that constructed and operated the plant agreed that the effluent on analysis should be found to be equal to the waters of Lake Mendota and the analyses of Lake Mendota water which was adapted as a standard of purity is reproduced in the Engineering News Vol. 42 No 26 pp 414. Samples of the crude sewage tank effluent

and filter effluent were taken and analysed as shown in Table II. A comparison of this table with the standard shows that in no particular does the effluent from the plant come up to the standard.

The company has since abandoned the contract and the city is considering other methods of disposal and purification "in order that there may be no more fiascos in civil engineering at the seat of this well known school." (University of Wisconsin)

TABLE II.

Analyses of Sewage and Effluent from Chemical Precipitation Plant and Filter Beds at Madison, Wis.

Parts per 1,000,000.

	November 23. 1900					
	Chemical Precipitation			Filter-beds.		
	Sewage	Effluent.	Efficiency	Sewage	Effluent.	Efficiency
Oxygen consumed: Total.	38.3	23.2	40%	23.2	14.3	38%
In suspension.	27.2	12.1	55%	12.1	3.5	71%
In solution.	11.1	11.1	00%	11.1	10.8	3%
Nitrogen as albuminoid ammonia.						
Total.	8.32	4.00	52%	4.00	2.46	38%
In suspension.	7.12	2.56	64%	2.56	1.60	37%
In solution.	1.20	1.44	-20%	1.44	.864	40%
Total organic nitrogen.	15.30	5.32	67%	5.32	3.56	33%
In suspension.	12.48	1.86	85%	1.86	1.54	17%
In solution.	2.82	3.46	-23%	3.46	2.02	42%
Nitrogen as free ammonia.	32.0	32.0	0%	32.0	32.0	0%
" " nitrites.						
" " nitrates.	.120	240		0.240	0.60	
Chlorine as chlorides	134	136		136	119	

Another example of the use of chemical precipitation is at Alliance, Ohio. There are three tanks each with a capacity of 144000 gallons. The amount of sewage flowing into the tanks during the year 1897 averaged about 300000 gallons per day. During the year 1897 each day 180 pounds of chemicals were added to the sewage and 650 pounds of sludge was precipitated and pressed daily.

The total cost of the disposal plant was $20755.00. The cost of operation and maintenance for the years 1897 and 1898 was $1290.00 and $1567.43 respectively. The average amount of lime used during this time was 95000 pounds yearly.

Two men perform all the labor necessary for the operation of the plant.

From the chemical analyses given in the Engineering Record Jan 13-1900 of the sewage and effluent, averages representing five months show the efficiency in albuminoid ammonia to be 40 percent. and oxygen required 30 per cent.

Septic Tank

We will now discuss a very different process of treating sewage, the septic method. The septic tank consists of a tank from which generally the air and light are excluded and through which the sewage flows with a slow velocity, thus allowing the matter in suspension to settle to the bottom or rise to the top by reason of its specific gravity, there to be further acted upon or decomposed by bacteria. The currents should be so guided that they are distributed over a considerable depth and not allowed to disturb the sediment at the bottom or the material at the top. The darkened ill ventilated and modestly heated conditions in the tank are all conducive to the propagation of a micro organism known as bacteria. The activity of these organisms causes a chemical decomposition of the organic matter in the sewage a part passing off as gas and a

part passing off in the effluent as inorganic matter, while another portion is deposited in the bottom of the tank as sludge

So far only matter in suspension has been considered but it is also true that chemical action takes place to some extent in the organic matter in solution. This chemical action is a denitrifying action similar to that which takes place in intermittent downward filtration

An important fact in the septic tank effluent is that its compounds have been broken down and it can now be more readily purified

The septic tank process is self-regulating, self-acting, requires no attention except the occasional cleaning out of the sludge.

As an illustration of this process the septic tank at Champaign Illinois may be described

This tank although designed in 1895, has only been in operation since 1897. The dimensions of this tank are

37 by 16 by 5 feet and it has a cubic capacity of 22000 gallons. It has taken care of a dry weather flow of 300000 gallons per day, about 13 times its cubic contents. The tank has operated with a range of from 11 to 27 times its cubic capacity with a high efficiency of purification though much of this was ground water.

The reduction of the organic matter in suspension, as shown by the reduction of oxygen consumed, nitrogen as albuminoid ammonia, and total organic nitrogen in three analyses averaged 94 percent. However it is not considered that an average of more than 80 to 90 percent may generally be expected. The reduction of organic matter in solution is considerable, averaging 17 per cent.

The sludge at the bottom is a black muddy looking silt like deposit containing about 66 percent of water and 5 per cent of organic matter. Its value as a fertilizer is small.

Although the amount of sludge is relatively small the accumulation requires removal occasionally, three or four times a year.

It is estimated that for every 1,000,000 gallons sewage there is about 3 cubic feet of dry matter. By chemical precipitation this would amount to from 20 to 25 cubic feet per 1,000,000 gallons.

Another good example of the septic tank method is the one in use at Exeter, England.

This plant has been in operation since 1896. It was designed for 98000 gallons capacity. The sewage is allowed to remain in the tank nearly 24 hours. The tank is used in conjunction with five beds in which further purification is used. The beds are filled with coke breeze and one is always resting for a week at a time. The tank is made nearly air tight by an arched roof and any gases collecting may be burned at a vent.

The rate of working this tank

is much slower than the process at Champaign Illinois

At Southwold England, there is another good illustration of this method. This has been called an open septic tank and is used in conjunction with two beds, an anaerobic, and an aerobic bed, the latter containing polarite.

This plant is interesting from the fact that the effluent from the anaerobic bed is distributed over the aerobic bed by means of a revolving sprinkler which prevents the liquid from passing unequally through the large grain, porous material. The action upon these beds is continuous

From a report of this system the analyses of gas found in three samples are as follows:–

	Oxygen	Nitrogen	Carbon dioxide	Sulphuretted hydrogen.
Septic tank.	0.25 %	28.46 %	70.03 %	1.26 %
Anaerobic bed.	7.26 %	39.10 %	52.37 %	0.91 %
Aerobic bed	20.62 %	78.63 %	0.75 %	0.00 %

Contact Bed.

The contact bed as distinguished from the bacteria bed may be said to be made up of fine material, while the bacteria beds are built of coarse material. The latter are used for taking out the rougher solids, and the former for taking out the more finely divided material, and the organic matter in solution. While this distinction is not commonly made it seems to be growing into usage

In the process of purification by means of contact beds the sewage is applied intermittently by distributing pipes or troughs so as to slowly fill the beds which are filled from a depth of from three to six feet with any kind of hard, porous, jagged material. The change which takes place is due to the action of certain bacteria in the presence of air. Although this process is not a new one, the method by which the results

were obtained was not fully understood until the more recent discoveries in the science of bacteriology were made.

The beds are made water tight to a depth of about four feet, the bottom being channeled or tiled to drain the effluent either to a secondary bed or into the effluent channel.

Many eminent men have advocated special material as coal, coke, clinker slag, sand, and gravel, and even glass for filling material. The results do not differ materially and Prof. L. P. Kinnicutt in an article in the Journal of the Association of Engineering Societies, February 1900 makes the following statement. "The material should be more or less porous so as to have a larger water absorbing area and have a jagged surface on which the gelatinized micro-organisms can be easily retained"

"The quantity of sewage that can be successfully treated by intermittent filtration has been shown not to be

over 100000 gallons per acre per day, a quantity so small as to be quite useless for towns and cities which would be obliged to construct beds with sand not "in situ". This point was quickly perceived in England where sand "in situ" is not of common occurence. These bacteria beds were not used long before the problem arose:- Can the amount of land required by the intermittent filtration method be so reduced that the construction of artificial bacteria beds will be a practical possibility?

"The results of the investigators started by this problem have given us what is known as the contact system of treatment and the septic tank treatment and have apparently shown not only that by combining these two methods the amount of area required for 100000 gallons can be reduced from one acre to about one seventh of an acre but also that the bacterial treatment is possible with sewage containing manufacturing refuse, and have outlined how sewage containing storm water may

be treated."

It has been found by experiment that after two or three weeks there is a marked reduction in the initial capacity of the tank due to breaking down of the filling material and also to the filling material becoming charged and coated over with a gelatinous slime consisting of living organisms and organic matter in the process of transformation.

If the bed is not overworked the capacity of the tank will remain constant after the first two or three weeks, showing that the durability is unlimited.

The beds are usually filled in half an hour, and the sewage allowed to remain on them about two hours when the effluent is run off and the beds allowed to rest several hours before again being filled.

By contact beds in series, the number depending upon the kind

of sewage, almost any degree of purification can be obtained

The Engineering Record of Jan. 27 1900 gives a very interesting account of the sewage disposal works at Sutton, England. The works were constructed in 1891 – 93, and comprise an area of 28 acres, 18 acres only being capable of irrigation. They were originally designed for chemical precipitation and broad irrigation. but after giving these methods a two years trial the local board found itself unable to satisfy the requirements of the Conservators of the River Thames, into which the effluent flowed.

Mr. W. J. Dibdin advised the construction of filters or fine grained bacteria beds. Two beds having a combined area of a quarter of an acre and a capacity of 200000 gallons, were built in 1895 – 96 for the purification of the chemically treated sewage. In 1896 the first bacteria bed was constructed for the treatment of crude sewage.

As previously stated many tests were made to determine the best kind of material for filling the beds.

The crude sewage, after being screened to intercept floating matter, is run directly onto the filters without the addition of any chemicals. After remaining in the beds for a period of two hours the effluent is in a fit condition to be discharged into the brook leading to the Thames and is uniformly superior to the effluent obtainable by local land treatment.

All experiments with bacteria beds show that the objects for which they were intended, to abolish sludge, has been realized and that sewage can be purified without chemicals at a small cost, being but little more than that incurred by the labor in attending to, or supervising the filling and discharging the filters and that sewage purification can be carried on with little or no nuisance.

Discussion.

The amount of purification to to be obtained by dilution depends upon the size of the stream into which the sewage is discharged and also upon the amount of oxygen contained in the stream. The latter condition is controlled very largely by the rate of flow of the stream and its previous condition of pollution. Mr. E. P. Stearns in his report to the Massachusetts State Board of Health, 1890, on Pollution and Self-Purification of Streams, gave a table showing the calculated amount of free ammonia dissolved solids and chlorine which sewage adds to running streams.

Much interest is being taken in the effect of the discharge of the sewage of Chicago, and the waters of Lake Michigan, into the Illinois River, and the outcome of the analyses of samples taken along the river

is awaited with interest. Published reports have not been given out, but information from the most reliable sources seem to show that a considerable purification takes place in the passage down the river.

No reliable data could be obtained giving the percent of purification by irrigation. At Berlin the sewage is purified by this method, and the effluent comes well within the requirments of the German law.

With chemical treatment about 90 percent of the matter in suspension and a small percent of that in solution is removed, and the purification is about 53 percent of the total organic matter.

The best examples of intermittent downward filtration show an efficiency of 95 percent on the total organic matter. However if this process is used in connection with other methods the organic matter may

be reduced 99 percent and the chemical analyses of the effluent may fill the drinking water requirments.

Results of analyses of sewage and effluent from septic tanks, show an efficiency of from 85 to 90 percent in the organic matter in suspension Very little change takes place in the matter in solution.

The result of experiments with a single contact bed at Sutton, England, from November 1896 to March 1898 shows a purification of 64 percent: if however two beds are used in series a further purification of 50 percent is obtained or a total purification of 82 percent of the crude sewage.

The capacities of irrigation, and intermittent downward filtration plants, and contact beds are usually stated in terms of the number of gallons per acre per day.

Table III shows the capacity of representative plants. Best authorities

TABLE III.

RATE OF SEWAGE TREATMENT.

System.	Location.	Sewage treated in gallons per acre per day.
IRRIGATION.		
	Berlin, Germany.	18,000.
	Manchester, Eng.—Estimated but not constructed.	18,500.
INTERMITTENT DOWNWARD FILTRATION.		
	Framingham, Mass.	19000.
	Leicester, "	38 750.
	Brockton, "	44 000.
	Marlborough, "	54 000.
	Gardner, "	140 000.
	Mendota, Ills.	184 000.
	Worcester,* Mass.	322 000.
	"* " (Fletcher's estimate).	500 000.
	Madison,* Wis.	8 000 000.
CONTACT BEDS.		
	Manchester, Eng. (crude sewage)	500 000.
	" * "	700 000.
	" " storm water sewage	2,500 000.

*Secondary filtration.

consider 100,000 gallons per acre per day to be the maximum rate permissible under the best conditions for the treatment of crude sewage by the intermittent downward filtration system. With unfavorable conditions the quantity of sewage should be limited to as low as 20,000 gallons. Wherever too large a dose is applied to the bed the sewage is not properly purified and the beds soon become clogged up and unfit for further use.

When the beds are used for secondary purification 750,000 gallons may be treated per acre per day.

The results of extensive experiments made at Manchester England in 1898 and 1899, show that by means of contact beds crude sewage may be treated at the rate of 500000 gallons per acre per day. When the beds are used for secondary purification 750000 gallons may be successfully treated, and storm water sewage treated at the rate of 2500000 gallons

per acre per day.

The capacity of the chemical precipitation plant at Madison, Wisconsin is 68 percent of the daily flow, which in 1899 was estimated at 300000.

The company that built the plant agreed that the plant should have a daily capacity of 1,200,000 for each and every day in the year. This shows the estimated capacity of the tank to be 28 per cent.

At Worcester one of the best examples of this process is in operation. The size of the tanks is equal to 28 percent of the total flow of 17.1 million gallons per day of which 10.1 million gallons is the out flow from a comparatively clear pond. If the actual amount of sewage is considered the tanks have a capacity of 65 percent of the total flow.

Rafter and Baker in their discussion of the size of tanks recommend that the total capacity should be nearly 50 percent of the

average daily flow.

The two typical types of septic tanks are those at Exeter, England and at Champaign Illinois. The first has a cubic capacity of 93 percent of the total daily flow, while the second has a capacity of 7.5 percent of the daily flow.

When the capacity of the tank is as small as at Champaign the bacteria do not have time to act upon the sewage as they would if the flow was not so rapid.

It is conceded now by the highest authorities on this subject that the tank should have a capacity equal to from one fourth to one half of the average daily flow.

Concerning the conditions for which the various processes are applicable, it may be said that the dilution process is used when advantage may be taken of natural resources. This method can be utilized by most cities situated along rivers or streams large enough to sufficiently dilute

and carry away the sewage, and fulfil sanitary requirements.

As an example of the use of dilution the Chicago River may be cited. Here the uncertain flow of the river was made to pass inward toward the Illinois River with a speed of 2½ miles per hour and a discharge of 20000 gallons per minute per 100000 inhabitants. The Blackston River was used by the cities of Massachusetts until the pollution of the river became unbearable and the state was compelled to pass law forcing the cities to purify their sewage.

Broad irrigation is a method which cannot generally be used on account of the large amount of land and labor required. This method is especially applicable to asylums, alms houses, and reformatories where cost of labor is small. It is used in the West where the value of all available water leads to the application of sewage to crops,

and also on account of the low stage of western streams during the summer which renders sewage discharged into them an unbearable nuisance.

Intermittent downward filtration may be used where there is a considerable area of sandy soil. and also where a high degree of purification is necessary.

Chemical precipitation does not require a large area for its operation and used alone does not give a high degree of purification Where land and material for beds is expensive, and partial purification is sufficient, this system may be used.

The septic tank requires a small area. The odors are not offensive and cannot be noticed 100 feet away. The effluent may be discharged into small streams and soon lose its identity.

Contact beds are used where a high degree of purity is required; if the

effluent is emptied into rivers or sources of water supply. The beds do not require a large area and the process may be recommended if suitable material is at hand.

The cost of construction and maintenance of the different systems vary so largely according to local conditions that a fair estimate is not possible, As the most striking example of maximum and minimum cost the disposal systems at Chicago and at Lowell, Massachusetts may be cited. The purification in both cases is by dilution, the cost being practically nothing at Lowell while the Chicago Drainage Canal cost $33000000. It may not be fair to charge this entire cost to the sewerage system; nevertheless up to date it has been used for no other purpose.

At Berlin Germany where broad irrigation is used, the sewage has to be pumped to the farms and involves a considerable cost. Aside from this the receipts derived from the

sale of farm products are enough to pay the running expenses of the farm.

The first cost of the intermittent downward filtration plant is estimated by the writers at $90000 per million gallons per day of sewage treated, where the beds are artificial. Where natural beds can be used the first cost may be reduced to $7500 per million gallons per day. The cost of maintenance is about $2.00 per 1,000,000 gallons.

The average cost for operating a chemical disposal plant is about 58 cents per inhabitant per year, or $16.00 per 1000000 gallons treated. At Manchester England where broad irrigation and chemical precipitation are used in combination, the average cost was $63.00 per 1000000 gallons treated.

A septic tank for treating 1000000 gallons of sewage per day will cost less than $10000 and the cost of maintenance will be about $1.00 per

1000000 gallons treated.

Conclusion

In selecting a method of sewage disposal, the conditions, surroundings, and requirements of the city should be carefully studied and analyzed, and judgment and discretion must be used. A matter of so much importance to the community should be placed in the hands of men qualified to make a proper solution of the problem. While in general several methods of purification may be applied to the requirements of the city, usually local conditions and considerations will narrow the choice to two plans or possibly to a single method.

The governing features of the dilution process are so distinct that it is not usually difficult to determine where this method is applicable, and likewise, the broad irrigation process has peculiar conditions. In both, the

plans involve only matters of construction.

The other methods have more in common and the determination of thier relative value is not so easy. As before stated, the recently developed biolytic processes promise to displace chemical precipitation Where a suitable deposit of sand or gravel is conveniently located on cheap land which may be made without great expense into filtration areas and the sewage discharged upon them by gravity, intermittent downward filtration may be the most satisfactory, especially if a highly purified effluent is desired. The item of expense of attendance, and labor of maintenance must be considered in connection with the cost of this method. In the absence of such favorable conditions and especially where complete purification is not required the septic tank may be the most suitable. For higher purification the combination of the septic

tank with filter beds, or contact beds run at comporatively high rates, makes a satisfactory purification and is applicable to a wide range of conditions. A bacteria bed may be substituted for the septic tank for the roughing process but its applicablity is not so general.

In conclusion it may be said that if the next ten years gives as much development in sewage purification as has the last decade, some of the processes herein outlined will have been discarded and sanitary engineering will have achieved still greater triumphs.